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ABSTRACT

This description of a methodology for examining the supply of educated manpower and the demand for their services consists of two major sections, which are devoted to the supply and demand of educated manpower respectively. In the first section, the supply of educated manpower and the demand for educational inputs are considered, the main discussion centering on production of educated manpower. In an illustration of the suggested approach, "educated manpower" is defined as the persons who attain a certain reading ability at a given educational level; and the "production function" is the production function of reading ability. Based on an empirically estimated production function of reading ability for U.S. public schools, the author examines whether the "teachers-don't-count" hypothesis can be accepted and indicates how questions as to whether U.S. public schools operate efficiently can be answered. In the second section the demand for educated manpower and the supply of other goods and services are considered based on the production functions of various industries requiring educated manpower (Only the aggregate production function, using income or earning data as a measure of output, are examined.) The last section considers some of the implications and limitations of the study. (Author/WL)

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# RESEARCH MEMORANDUM

## THE ROLE OF EDUCATION IN THE SUPPLY AND DEMAND OF EDUCATED MANPOWER

Kan Hua Young

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Educational Testing Service
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# The Role of Education in the Supply and Demand of Educated Manpower

Kan Hua Young

Educational Testing Service

## 1. Introduction

In recent years the role of education and human capital in economic growth and income distribution has received considerable attention from many prominent economists, particularly G. S. Becker [2] and T. W. Schultz [15]. Becker and Schultz, while clearly recognizing the interplay of the forces between supply and demand of educational services, tended to emphasize the individual demand and rational choice of educational level. The same is true for all contributions following the "human capital approach" that were reviewed by J. Mincer [14]. On the other hand, following the publication of Equality of Educational Opportunity, or the Coleman Report [3], and its subsequent study [13], many economists became interested in the controversial "teachers-don't-count" hypothesis and its related issues. To answer these questions, economists typically attempted to estimate some "educational production functions," and thus tended to emphasize the supply rather than the demand of education. In both situations, the focus had been the educational services, not the product of their services; i.e., the educated manpower, not necessarily teachers. The purpose of this paper is to describe a methodology for examining the supply of educated manpower and the demand for their services. The term "educated manpower," however, is defined narrowly as the persons who possess a certain level of reading ability at a certain level of education, or who have completed a certain level of education.

The production functions of educated manpower and of other goods and services which require the services provided by educated manpower form the basis of the following entire discussion. It will be shown that the key to a cost-benefit analysis or budgeting and planning for an educational system is a reliable estimate of these production functions. Whether the cost of education, as suggested by W. Baumol [1], will be skyrocketing in the future is also determined by the nature of these production functions. In estimating the production function of educated manpower, we expect to derive a supply or cost function which is consistent with an efficient allocation of educational resources so that the efficiency of an educational system can be evaluated by comparing the observed cost with the minimum cost implied by the cost function. On the other hand, in estimating the production function of other goods and services which require educated manpower as an input, we hope to determine the derived factor demand for educated manpower so that the optimum level of educational effort can be indicated. Although there are some recent studies which are related to either supply or demand of educated manpower, most studies have either failed to consider both factors together or have concentrated only on higher education.

The role of a school system can be viewed either as that of supplying educational services to individuals or supplying educated manpower to industry. The first view is more appropriate in discussing private return, but the second is more relevant to the issue of public return to education. Since we shall be taking the public point of view, a school system will be viewed as the producer of educated manpower which

is employed either by the school system or by other industries for producing other goods and services.

The present paper consists of two major sections, which are devoted to the supply and demand of educated manpower respectively. In Section 2, the supply of educated manpower and the demand for educational inputs are considered. The main discussion centers on production of educated manpower. In an illustration of this approach, "educated manpower" is simply defined as the persons who attain a certain reading ability at a given educational level. Therefore, the production function is essentially the production function of reading ability. Based on an empirically estimated production function of reading ability for U. S. public schools, we examine whether the "teachers-don't-count" hypothesis can be accepted or indicate how questions as to whether U. S. public schools operate efficiently can be answered. In Section 3, the demand for educated manpower and the supply of other goods and services are studied. The conceptual basis of this discussion is the production functions of various industries which require educated manpower. Since a comprehensive analysis of all relevant industries, taken separately, is certainly beyond the scope of the present study, we examine only the aggregate production function, using income or earning data as a measure of output.[1] Many studies have attempted to estimate the relationship between earning and schooling or ability (e.g., [4], [8] and [9]). However, the point of view taken by these studies appears to be more closely related to individual demand for education than to industrial demand for educated manpower.[2] Finally, in the last section, we consider some of the implications and limitations of the present study.

## 2. Supply of Educated Manpower and Demand for Educational Inputs

### 2.1 Production Technology: The Production Function of Education

The purpose of this section is to present a conceptual framework for the analysis of the supply of educated manpower. Since the general theory of production function is relatively well known, we shall proceed in a more specific manner by considering how an empirically applicable production function of education can be meaningfully specified. Unlike most other production functions where the outputs are relatively easy to measure, in the case of education the output is not easily quantifiable. The most convenient measures of educational output are usually related to years of schooling completed or the achievement level of some cognitive skill such as the scores of I.Q. or some other achievement tests.[3] Existing evidence suggests that most of these measures are highly correlated and reading ability appears to be a good measure of educational output, especially for the lower levels of elementary schools. For our purpose, we shall, therefore, assume that schools are producing students with a certain level of reading ability, and that their outputs are measured by the number of students who achieve the given standard of reading ability at a certain grade level.

As in usual production functions, the educational inputs may be classified into capital and labor. In order to take into account quality variation, quality of capital and labor are also considered. While the quantity of labor can be reasonably measured by the numbers of teachers, the quantity of capital, or more appropriately its service, can be approximated by the number of classrooms, the volume of books, etc.

The quality of capital and labor are, however, much more difficult to measure.

For empirical applications, despite some limitations, the production function of education for a given school may be represented by a Cobb-Douglas form. Thus, we have

$$(1) \qquad N = \exp(\alpha_0)\, K_n^{\alpha_1} K_q^{\alpha_2} L_n^{\alpha_3} L_q^{\alpha_4}$$

where $N$ = the number of students who achieve the given level of competence: e.g., national median of reading ability;

$K_n$ = the amount of capital: e.g., the number of classrooms;

$K_q$ = the amount of superior capital: e.g., the number of nonimprovised classrooms;

$L_n$ = the number of teachers;

$L_q$ = the number of superior teachers: e.g., the number of teachers who possess a certain level of verbal ability.

The simple production function Eq. (1) can be modified easily by allowing the parameters $\alpha$'s to vary according to the size of the educational system, the racial composition of the student body, and the economic status of the family. For the purpose of empirical estimation, we may specify these parameters as

$$\alpha_0 = \beta_0 + [1 + (\beta_1 - \beta_4 - \beta_8) + (\beta_2 - \beta_5 - \beta_9)\, \ell n\, M + (\beta_3 - \beta_6 - \beta_{10})\, \ell n\, S]\, \ell n\, M$$

$$\alpha_1 = (\beta_4 - \beta_7) + \beta_5\, \ell n\, M + \beta_6\, \ell n\, S$$

$$\alpha_2 = \beta_7$$

$$\alpha_3 = (\beta_8 - \beta_{11}) + \beta_9\, \ell n\, M + \beta_{10}\, \ell n\, S$$

$$\alpha_4 = \beta_{11}$$

which, after some rearrangements, becomes

$$(2) \qquad \left(\frac{N}{M}\right) = \exp(\beta_0)\, M^{\beta_1 + \beta_2\, \ell n\, M + \beta_3\, \ell n\, S} \left(\frac{K_n}{M}\right)^{\beta_4 + \beta_5\, \ell n\, M + \beta_6\, \ell n\, S} \left(\frac{K_q}{K_n}\right)^{\beta_7} \left(\frac{L_n}{M}\right)^{\beta_8 + \beta_9\, \ell n\, M + \beta_{10}\, \ell n\, S} \left(\frac{L_q}{L_n}\right)^{\beta_{11}}$$

where

M = the number of students in a given school (at a given grade);

S = socioeconomic variables; e.g., racial composition of the student body or the economic status of the family.

The estimation of Eq. (2) can be easily accomplished, since it becomes a linear form after logarithmic transformation. It can be easily verified that the return to scale to a proportional variation of the quantities and qualities of capital and labor is $(\beta_4 + \beta_8) + (\beta_5 + \beta_9)\, \ell n\, M + (\beta_6 + \beta_{10})\, \ell n\, S$ . Note that the variable (N/M) is

the proportion of students who achieve a certain level or standard, $(K_n/M)$ and $(L_n/M)$ are the capital-student ratio and the teacher-student ratio, $(K_g/K_n)$ and $(L_g/L_n)$ are the proportions of nonimprovised capital facilities and well-qualified teachers. As shown in Eqs. (1) and (2) the output of a school system can be measured by either $N$ or $(N/M)$. There are four categories of educational inputs, $K_n$, $K_g$, $L_n$ and $L_q$, in addition to the school characteristics $M$ and $S$, that are explicitly included in the production function.

2.2 Production Efficiency: The Cost Function of Education

The previous discussion concerns only technical feasibility or the state of the art in educational potential. It did not deal with any economic considerations regarding the allocative efficiency of various inputs and the resulting costs of education. Economists have shown that in order to be efficient in the sense of minimum cost for a given output or maximum output for a given expenditure, the factor inputs must be combined in such a way that each pair of marginal product ratio must equal the corresponding price ratio. Furthermore, based on this efficiency assumption, it is relatively straightforward to show how the derived demand for various educational inputs is determined by the factor prices and the level of output. Frequently we may hear the objection to this approach on the ground that the efficiency assumption is extremely unrealistic in most situations, particularly in education where the outputs are not easily quantifiable. It is not generally realized, however, that such an efficiency assumption is not really as critical as it may appear to be in order to obtain the derived demands for factor inputs

realistically. In fact, once the efficiency assumption is relaxed, it is only necessary to substitute the "imputed prices" (which are implied by the observed combination of factor inputs if the allocation is to be efficient) for the observed prices in order to derive the observed cost function which may not be the minimum cost function. In principle, these "imputed prices" of factor inputs can always be derived from the observed combination of the factor inputs, the level of output, and the cost of production.

For the convenience of exposition, let us consider the production function shown as Eq. (1), where the output is $N$ and the factor inputs are $K_n$, $K_g$, $L_n$, and $L_q$. In this case, the return to scale is simply $\Sigma_{i=1}^{4} \alpha_i$. Denoting the prices associated with substandard capital and less qualified teachers as $r_1$ and $w_1$ respectively, and the prices associated with superior capital and well-qualified teachers as $r_2$ and $w_2$ respectively, then the efficiency assumption requires

$$(3a) \qquad \frac{(\partial N/\partial K_n)}{(\partial N/\partial K_q)} = \frac{r_1}{r_2}$$

$$(3b) \qquad \frac{(\partial N/\partial K_q)}{(\partial N/\partial L_n)} = \frac{r_2}{w_1}$$

$$(3c) \qquad \frac{(\partial N/\partial L_n)}{(\partial N/\partial L_q)} = \frac{w_1}{w_2}$$

From Eqs. (1) and (3), it is possible to solve for $K_n$, $K_q$, $L_n$ and $L_q$ in terms of factor prices $r_1$, $r_2$, $w_1$, $w_2$ and the level of output $N$. These results, together with the cost equation defined as

$$C = r_1 K_n + r_2 K_q + w_1 L_n + w_2 L_q \tag{4}$$

enable us to derive the cost function as

$$C = A(p, \alpha) N^{1/(\Sigma_{i=1}^{4} \alpha_i)} \tag{5}$$

where $A(p, \alpha)$ is a scale factor, and $p$ and $\alpha$ are the price and the parameter vectors respectively. As pointed out earlier, once the efficiency assumption is relaxed, in order to derive the cost function realistically, we need only to substitute the imputed prices, say $p^*$, for the observed price $p$ in the cost function given as Eq. (5). Intuitively it is, therefore, very appealing to define the index of cost efficiency (or inefficiency) as

$$E = A(p^*, \alpha) \; / \; A(p, \alpha) \geq 1 \tag{6}$$

where the value of one indicates perfect efficiency. The implementation of the idea for an evaluation of production efficiency requires a reliable estimation of the production function, through which not only the parameter values $\alpha$ are to be obtained but also the imputed prices $p^*$ are to be derived. In addition, the data of observed prices $p$ must also be available; otherwise they must be estimated separately. The argument is essentially the same, if we prefer to use (N/M) as a measure of output, instead of using $N$.

2.3 Empirical Results

The theoretical framework discussed above has been implemented for empirical analysis, using the data available from Equality of Educational Opportunity. Specifically, the test scores of reading ability of the sixth grade students in more than 2,000 U. S. public schools are analyzed by estimating the production function specified in Eq. (2). In addition, several special cases of this formulation are also examined. The results of these analyses are summarized in Table 1. In this table,

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Insert Table 1 about here

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Regression I is the special case of Eq. (2) where $\beta_2$, $\beta_3$, $\beta_5$, $\beta_6$, $\beta_9$ and $\beta_{10}$ are assumed to be zero. Regressions II and IV are formally identical in assuming $\beta_2$ and $\beta_3$ to be zero, but the data used for socioeconomic variable S are defined differently. Similarly, the only difference between Regressions III and V is the data used for socioeconomic variable S . Regressions II and III are intended for testing the hypothesis that the production technology or return to scale may be different for schools with different racial composition of student body in addition to their size. The variable S in these two regressions is defined as the proportion of white students. On the other hand, Regressions IV and V are intended for testing the hypothesis that the production technology or return to scale may be different for schools with students from families of different economic status in addition to their size. The variable S in these two regressions is defined as an index of material objects representing the economic status of the families serviced by a given school. In general, we find that economic

status appears to be more likely to account for possible difference in production technology when it is compared with racial composition.

Return to capital. The return to scale of a proportional change of both the quantity and quality of capital, according to Eq. (2), is simply $\beta_4 + \beta_5 \ln M + \beta_6 \ln S$. Regression I suggests that the return to capital is generally low ($\beta_4 = 0.13$), indicating that only a 0.13% increase in output may be expected for a 1% increase of capital. Regressions II and III show essentially similar results, indicating that the return to capital is negligible for the average schools. These regressions further show that the return to capital may be lower for large schools and predominantly white schools, since both the estimated values of $\beta_5$ and $\beta_6$ are negative. Regressions IV and V also confirm the finding that the return to capital is generally very low. It is again found to be negligible for the average schools. In addition, these last two regressions also indicate that the return to capital may be lower for large schools and the schools in more affluent communities, since both the estimated values of $\beta_5$ and $\beta_6$ are negative.

Return to labor. The return to scale of a proportional change of both the quantity and quality of labor, according to Eq. (2), is simply $\beta_8 + \beta_9 \ln M + \beta_{10} \ln S$. Regression I indicates that the return to labor is considerably higher than the return to capital ($\beta_8 = 0.75 > \beta_4 = 0.13$), indicating a much higher percentage increase in output may be expected from a 1% increase of labor than from a 1% increase of capital. Regressions II and III support a similar conclusion. The return to labor,

according to these two regressions, for the average schools is approximately 0.5 to 0.6. There is some indication to suggest that the return to labor is lower for large schools and higher for predominantly white schools. The evidence, however, is not very conclusive, since the estimated values of $\beta_9$ and $\beta_{10}$ are not statistically significant.[4] Regressions IV and V provide us with some further results. In general, these regressions also confirm the findings obtained from other regressions, except whether the return to labor is larger or smaller in large schools. Notice that while the estimated values of $\beta_9$ are negative in Regressions II and III, they are positive in Regressions IV and V. However, none of these estimated values are statistically significant. These last two regressions also indicate that the return to labor may be lower for the schools serving more affluent communities, which are likely to have higher teacher-student ratio. Similar to Regressions II and III, they also indicate that the return to labor for the average schools is around 0.5. In general, our empirical evidence does not support the "teachers-don't-count" hypothesis, since the estimated values of $\beta_8$ and $\beta_{11}$ are generally statistically significant.

Cost function: Return to capital and labor. The previous discussions have considered the return to capital and labor separately. The return to scale of both capital and labor, according to Eq. (2), can be measured by $(\beta_4 + \beta_8) + (\beta_5 + \beta_9)\ \ell n\ M + (\beta_6 + \beta_{10})\ \ell n\ S$. The evidence provided by all our regression results shows that the return to scale is generally below one. Furthermore, these results also indicate that the return to scale appears to be lower for the large schools,

predominantly white schools, and the schools serving more affluent communities.

In our earlier discussion, we have demonstrated how the cost function can be derived from the production function under a certain condition. In particular, the cost function is shown to have a general form of Eq. (5) if the production function is in Cobb-Douglas form. Expressing the same result in terms of the parameters of Eq. (2), the cost function can be written as

$$(7) \qquad C = A(p, \beta)\, N^{1/\lambda}$$

where $\lambda = (\beta_4 + \beta_8) + (\beta_5 + \beta_9)\, \ell n\, M + (\beta_6 + \beta_{10})\, \ell n\, S$ , $A(p, \beta)$ is a scale factor, and $p$ and $\beta$ are the price and the parameter vectors respectively. The average cost function can be easily shown as

$$(8) \qquad \left(\frac{C}{N}\right) = w = A(p, \beta)\, N^{(1-\lambda)/\lambda}$$

where $w$ is the wage rate of educated manpower. Because of the non-profit nature of a school system in general, it may be argued that the average cost function given above may be regarded as the supply function of educated manpower. In this case, the elasticity of supply of educated manpower is simply $\lambda/(1-\lambda) > 0$, for $0 < \lambda < 1$ . We have already indicated that the return to scale is approximately 0.5 to 0.6; therefore, the elasticity of supply of educated manpower would seem to be more elastic than is commonly assumed. This particular result may be surprising but not unreasonable. In fact, if the demand for educated manpower fluctuated considerably with the economic condition, the fact

that the wage level of educated manpower is rigid would seem to indicate that its supply is probably elastic.

## 3. Demand for Educated Manpower and Supply of Goods and Services

### 3.1 Production Technology: The Production Function of the Economy

The previous section was mainly concerned with the supply of educated manpower. In contrast, the purpose of this section is to examine the demand for educated manpower. We have suggested that ideally it is preferable to study the demands for various occupations separately by examining the production functions of various industries. However, in the present paper we shall consider only the aggregate production function of the U. S. economy, from which we shall then attempt to infer the nature of the demand for educated manpower.[5]

The theoretical framework that will be followed in this section is similar to that employed in the previous section, except that the emphasis is now on the demands for factor inputs rather than the supply of output. The production function of all industries other than the educational system must now be considered. In practice, since we shall not be able to examine each occupation and each industry separately and shall not be able to single out the educational system, we shall merely attempt to study the production function of the economy as a whole. Such a production function can be approximated again by the Cobb-Douglas form introduced previously.

The production function of goods and services for the economy is formally identical to Eq. (1) or (2) and can be written as

$$(9) \qquad Y = \exp(\alpha_0)\, K_n^{\alpha_1} K_q^{\alpha_2} L_n^{\alpha_3} L_q^{\alpha_4}$$

which is exactly the same as Eq. (1), except the output is now the level of income $Y$ instead of the number of educated manpower $N$ produced annually. The other notation may now be redefined as

$K_n$ = total capital stock;

$K_q$ = advanced (or modern) capital of the more recent vintage;

$L_n$ = total labor force;

$L_q$ = educated manpower.

Similar to Eq. (2), by allowing some of the parameters $\alpha$'s to vary according to the size or the industrial composition, etc., we have the following production function for the economy

$$(10) \qquad \left(\frac{Y}{M}\right) = \exp(\gamma_0)\, M^{\gamma_1 + \gamma_2 \ln M + \gamma_3 \ln S} \left(\frac{K_n}{M}\right)^{\gamma_4 + \gamma_5 \ln M + \gamma_6 \ln S} \left(\frac{K_q}{K_n}\right)^{\gamma_7} \left(\frac{L_n}{M}\right)^{\gamma_8 + \gamma_9 \ln M + \gamma_{10} \ln S} \left(\frac{L_q}{L_n}\right)^{\gamma_{11}}$$

where the notation may be redefined as

$Y$ = personal income of, say, a given state;

$M$ = total population;

$S$ = industrial composition, such as proportion of non-agricultural population or rural-urban composition.

3.2 Production Efficiency: The Demand for Educated Manpower

In the discussion related to the prcduction function of an educational system, we have mentioned the demands for educational factor inputs very briefly and emphasized only the supply of educational output. In the present discussion of the production of the economy in general, on the other hand, we shall stress the demands for factor inputs, particularly the demand for educated manpower. While it is convenient to derive the demands for factor inputs based on an assumption of efficient factor allocation, as in the previous section, it will be argued that the demands for inputs can also be inferred without such an assumption once the "imputed prices" are derived.

As in the previous case, we may consider personal incomes $Y$ as the output of the economy and the factor inputs are $K_n$, $K_q$, $L_n$ and $L_q$, as shown in Eqs. (9) and (10). Denoting, as in the previous section, the prices of the capital of the early vintage and the less educated labor as $r_1$ and $w_1$ respectively, and the prices of the capital of the advanced (or modern) vintage and the well-educated labor as $r_2$ and $w_2$ respectively, then the efficiency assumption requires

$$\text{(11a)} \qquad \frac{(\partial Y/\partial K_n)}{(\partial Y/\partial K_q)} = \frac{r_1}{r_2}$$

$$\text{(11b)} \qquad \frac{(\partial Y/\partial K_q)}{(\partial Y/\partial L_n)} = \frac{r_2}{w_1}$$

$$\text{(11c)} \qquad \frac{(\partial Y/\partial L_n)}{(\partial Y/\partial L_q)} = \frac{w_1}{w_2}$$

which correspond to Eqs. (3a) to (3c). From Eqs. (10) and (11), it is possible to solve for $K_n$, $K_q$, $L_n$ and $L_q$ in terms of factor prices $r_1$, $r_2$, $w_1$, $w_2$, and the level of output $Y$. In particular, it can be verified that the demand for educated manpower may be expressed as

$$(12) \qquad L_q = B(Y, p, \alpha)\, w_2^{(\alpha_4/\Sigma_{i=1}^{4}\alpha_i) - 1}$$

in terms of the parameters of Eq. (9), or

$$(13) \qquad L_q = B(Y, p, \alpha)\, w_2^{(\gamma_{11}/\mu) - 1}$$

where $\mu = (\gamma_4 + \gamma_8) + (\gamma_5 + \gamma_9)\, \ell n\, M + (\gamma_6 + \gamma_{10})\, \ell n\, S$, in terms of the parameters in Eq. (10). When the efficiency assumption given in Eq. (11) is violated, it is only necessary to substitute the "imputed prices" $p^*$ for the observed prices $p$ in Eq. (12) or (13). For this reason, it is important to investigate how the "imputed prices" can be inferred from the observable data. In principle, by definition, the imputed prices $p^*$ can be obtained by solving the system of equations represented by any $n - 1$ factor demand functions such as Eq. (12) or (13) and the cost equation such as Eq. (4).

Similar to the index of cost efficiency defined in Eq. (6), it is possible to define the index of factor efficiency as

$$(14) \qquad E_x = B_x(Y, p^*, \alpha) \,/\, B_x(Y, p, \alpha) \gtrless 1$$

where the subscript $x$ indicates any given factor input. Like the cost efficiency index, the value of one indicates a perfect efficiency. Unlike the index of cost efficiency, the value can be either greater or less than one, indicating the particular factor is being over- or underemployed.

3.3 Empirical Results

The production function of the U. S. economy as specified in Eq. (10) has been implemented for estimation. The data used for this analysis are cross-sectional data by state obtained from the Statistical Abstract of the United States. Most of the data refer to 1970, except the data on education and property income, which are used to provide a rough estimate of capital stock. In this study, the data on education are for 1960 and those on property income are for 1968 and 1969. The data on capital stock have been estimated by assuming that the stock is 10 times 1969 property income for every state, and that the proportion of new capital is the same as the growth rate of property income from 1968 to 1969. These assumptions may be somewhat arbitrary, but they are not expected to affect the validity of our overall analysis.

The empirical results of the production function shown as Eq. (10) of the U. S. economy, together with some of its special cases, are summarized in Table 2. In this table, Regression I is the special

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Insert Table 2 about here

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case of Eq. (10) where $\gamma_2$, $\gamma_3$, $\gamma_5$, $\gamma_6$, $\gamma_9$ and $\gamma_{10}$ are assumed to be zero. Regressions II and IV are formally identical in assuming $\gamma_2$ and $\gamma_3$ to be zero, the only difference being the variables associated with $\gamma_2$, $\gamma_5$ and $\gamma_9$. In Regression IV the logarithmic value of population density is substituted for the logarithmic value of population itself which is used in Regression II. Similarly, Regressions III and V are formally identical, except the variables associated with $\gamma_2$, $\gamma_5$ and $\gamma_9$. In Regression V the logarithmic value of population density is substituted

for the logarithmic value of population itself which is used in Regression III. Regressions II and III are intended for testing the hypothesis that the return to scale may be different for states with different sizes of population and industrial compositions. Similarly, Regressions IV and V are intended for testing the hypothesis that the return to scale may be different for states with different population densities and industrial compositions. It appears that the results of Regressions IV and V are more satisfactory than those of Regressions II and III.

Return to capital. The return to scale of a proportional change of both the quantity and quality of capital, according to Eq. (10), is simply $\gamma_4 + \gamma_5 \ln M + \gamma_6 \ln S$. Regression I suggests that the return to capital is very low ($\gamma_4 = 0.04$), indicating that only 0.04% increase in personal income may be expected for a 1% increase of capital. Regressions II and III show essentially similar results, indicating that the return to capital is negligible for average states. These regressions further show that the return to capital is likely to be higher for more populous states and lower for less agriculturally oriented states, since the estimated values of $\gamma_5$ and $\gamma_6$ are positive and negative respectively. Regressions IV and V, however, indicate that the return to capital is much higher. For the average states, the return to capital is approximately 0.20 according to Regression IV and approximately 0.30 according to Regression V. The results of Regressions IV and V further suggest that the return to capital is higher for more densely populated states and lower for less agriculturally oriented states, since the

estimated values of $\gamma_5$ and $\gamma_6$ are positive and negative, respectively, a conclusion supporting the finding of Regressions II and III.

Return to labor. The return to scale of a proportional change of both quantity and quality of labor, according to Eq. (10), is simply $\gamma_8 + \gamma_9 \ln M + \gamma_{10} \ln S$. Regression I indicates that the return to labor is also likely to be very low, since $\gamma_8 = 0.01$ (with $\gamma_9 = \gamma_{10} = 0$). Regressions II and III confirm the same conclusion for average states and show that the return to labor may be lower for more populous states and less agriculturally oriented states, since the estimated values of $\gamma_9$ and $\gamma_{10}$ are either zero or negative. The conclusion that the return to labor may be very low is also supported by the results of Regressions IV and V for average states. The results of Regressions IV and V show that the return to labor is likely to be lower for more densely populated states, since the estimated values of $\gamma_9$ are either zero or negative. As to whether the return to labor is lower for less agriculturally oriented states, as indicated by the estimated values of $\gamma_{10}$, the results of Regressions IV and V contradict those of Regressions II and III.

Demand function: Capital and labor inputs. In the previous section, we have examined the return to capital and labor separately. As demonstrated earlier the return to both capital and labor can be measured by $\mu = (\gamma_4 + \gamma_8) + (\gamma_5 + \gamma_9) \ln M + (\gamma_6 + \gamma_{10}) \ln S$. The empirical evidence we have examined so far suggests that the return to scale $\mu$ is generally very low, providing a strong evidence to decreasing return to scale.

Returning to the demand function for educated manpower as shown in Eqs. (12) and (13), we find that the elasticity of demand is $(\gamma_{11}/\mu) - 1$. Therefore, assuming $\gamma_{11} > 0$ and $\mu > 0$, it is necessary to have

$\gamma_{11} < \mu$ for the elasticity to be negative. We have found that the value of $\mu$ is likely to be small, but the value of $\gamma_{11}$ is likely to be so small as to be negligible. Thus, we may conclude that the elasticity of demand for educated manpower is approximately minus one or slightly less elastic than minus one.

## 4. Implications and Limitations

In the previous two sections we have concluded that the supply of educated manpower is likely to be elastic and the demand for educated manpower is likely to be inelastic. These conclusions are not inconsistent with the facts that the wage and salaries of educated manpower tend to be rigid, and the employment situation may fluctuate considerably with changing economic conditions. But before we can accept these conclusions we must recognize the following important limitations.

The supply of educated manpower implied in Eq. (8) can be written more explicitly as

$$N(t) = [A(p, \beta)]^{(1-\lambda)/\lambda} w^{\lambda/(1-\lambda)} \tag{15}$$

where $N(t)$ represents gross increase of the supply of educated manpower. Total supply of educated manpower at a given time period is

$$L_q(t) = \Sigma_{\tau=0}^{\infty} [1-\delta(\tau)]N(\tau) \tag{16}$$

where $\delta(\tau)$ represents "retirement" rates of the educated manpower that entered the labor force $\tau$ periods ago. This is a very complicated function, which appears to be too difficult to simplify without introducing some drastic assumptions. It is important to note that while the

supply of educated manpower may be elastic for new labor forces, it is possible that viewed from the entire market of educated manpower it is very inelastic indeed.

The demand for educated manpower shown as Eq. (13) refers to aggregate demand at a given time period. The incremental demand, in fact, is much smaller, since most positions have already been filled. The incremental demand for educated manpower at a given time period is defined as

$$(17) \qquad N(t) = L_q(t) - L_q(t-1)$$

where $L_q(t)$ is the aggregate demand for educated manpower at $\tau$ time period. The aggregate demand for educated manpower itself may be written as

$$(18) \qquad L_q(t) = B(Y, p, \alpha)\, w^{(\gamma_{11}/\mu)-1}$$

which is identical to Eq. (13), except a notational change for the wage rate of educated manpower. Notice that while aggregate demand $L_q(t)$ may be inelastic, the incremental demand can be extremely elastic. Although the analysis of the market for educated manpower may be viewed from the analytical framework as represented by Eqs. (16) and (18), perhaps the alternative analytical framework as represented by Eqs. (15) and (17) can be implemented more easily. A more explicit analysis of the problem is beyond the scope of the present paper.

Finally, it must be pointed out that the definitions of "educated manpower" adopted in the present study are admittedly arbitrary. Furthermore, while in the study of supply, reading ability is used as a yardstick;

in the study of demand, years of schooling completed is used. In addition, in the study of supply, the unit of observation is school; but in the study of demand, the unit of observation is state. In interpreting our empirical results, we must keep these discrepancies in mind. In spite of these limitations, our empirical analyses appear to have provided some meaningful results.

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## Footnotes

[1]For a review of industry studies, see [10].

[2]An exception may be found in [12], where P. R. G. Layard *et al.* discuss the production function of the electrical engineering industry and its demand for educated manpower in England.

[3]See, for example, [6] for a survey of production in education.

[4]This result is not inconsistent with the finding of Hanushek [7], using the data from a California school system. He rejected the "teachers-don't-count" hypothesis for white but not Spanish-speaking students.

[5]The existing literature on the contribution of education to economic growth or the relationships between the earning and education generally fail to consider this theoretical background. See, for example, [4] and [11], and [5], [8], and [9].

TABLE 1: ESTIMATED PRODUCTION FUNCTIONS OF READING ABILITY IN U.S. PUBLIC SCHOOLS

| PARAMETER | REGRESSION RESULT | | | | |
|---|---|---|---|---|---|
| | I | II | III | IV | V |
| $\beta_0$ | 1.62<br>(6.74)* | 2.39<br>(3.00)* | 2.83<br>(3.54)* | 2.99<br>(4.02)* | 4.03<br>(5.41)* |
| $\beta_1$ | 0.29<br>(7.76)* | -0.32<br>(-1.41) | -0.15<br>(-0.63) | -0.47<br>(-2.21)* | 0.28<br>(1.03) |
| $\beta_2$ | --<br>-- | --<br>-- | -0.13<br>(-5.34)* | --<br>-- | -0.15<br>(-6.56)* |
| $\beta_3$ | --<br>-- | --<br>-- | -0.06<br>(-4.67)* | --<br>-- | -0.27<br>(-2.47)* |
| $\beta_4$ | 0.13<br>(1.39) | 0.19<br>(0.55) | 0.67<br>(1.85) | 2.36<br>(5.88)* | 3.86<br>(8.48)* |
| $\beta_5$ | --<br>-- | -0.14<br>(-1.52) | -0.34<br>(-3.43)* | -0.21<br>(-2.38)* | -0.46<br>(-4.97)* |
| $\beta_6$ | --<br>-- | -0.08<br>(-5.38)* | -0.13<br>(-7.65)* | -0.84<br>(-5.52)* | -1.19<br>(-7.03)* |
| $\beta_7$ | 0.10<br>(1.55) | 0.04<br>(0.64) | 0.01<br>(0.21) | 0.01<br>(0.23) | -0.02<br>(-0.04) |
| $\beta_8$ | 0.75<br>(4.90)* | 1.17<br>(2.48)* | 1.08<br>(2.26)* | 1.85<br>(1.97)* | 1.62<br>(1.72) |
| $\beta_9$ | --<br>-- | -0.16<br>(-1.24) | -0.12<br>(-0.91) | 0.05<br>(0.42) | 0.04<br>(0.35) |
| $\beta_{10}$ | --<br>-- | 0.03<br>(0.64) | 0<br>(0.01) | -0.77<br>(-1.56) | -0.61<br>(-1.20) |
| $\beta_{11}$ | 0.39<br>(26.52)* | 0.24<br>(15.26)* | 0.21<br>(13.90)* | 0.18<br>(11.82)* | 0.16<br>(10.80)* |
| $R^2$<br>F | 0.35<br>226.57 | 0.45<br>195.89 | 0.47<br>170.51 | 0.52<br>258.72 | 0.54<br>223.63 |

Notes: 1. The figures in parentheses are t-values.
2. An asterisk (*) indicates significance at 5% level.

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TABLE 2: ESTIMATED AGGREGATE PRODUCTION FUNCTIONS OF U.S. ECONOMY

| PARAMETER | REGRESSION RESULT | | | | |
|---|---|---|---|---|---|
| | I | II | III | IV | V |
| $\gamma_0$ | 7.04<br>(45.68)* | 7.37<br>(8.44)* | 7.09<br>(8.60)* | 7.20<br>(25.87)* | 7.13<br>(20.71)* |
| $\gamma_1$ | 0.04<br>(2.70)* | -0.14<br>(-1.24) | -0.66<br>(-3.74)* | 0.02<br>(1.33) | 0.26<br>(1.64) |
| $\gamma_2$ | --<br>-- | --<br>-- | 0.01<br>(0.61) | --<br>-- | 0.01<br>(0.84) |
| $\gamma_3$ | --<br>-- | --<br>-- | 0.16<br>(3.50)* | --<br>-- | -0.07<br>(-1.60) |
| $\gamma_4$ | 0.04<br>(3.12)* | 0.09<br>(1.29) | 0.10<br>(1.66) | 0.05<br>(1.00) | 0.03<br>(0.50) |
| $\gamma_5$ | --<br>-- | 0.09<br>(1.68) | 0.20<br>(3.36)* | 0.10<br>(4.93)* | 0.11<br>(3.51)* |
| $\gamma_6$ | --<br>-- | -0.24<br>(-2.72)* | -0.44<br>(-4.26)* | -0.11<br>(-2.-6)* | -0.09<br>(-1.63) |
| $\gamma_7$ | 0.01<br>(1.40) | 0<br>(1.23) | 0<br>(0.80) | 0<br>(0.38) | 0<br>(0.72) |
| $\gamma_8$ | --<br>-- | 0.13<br>(2.73)* | 0.18<br>(4.04)* | -0.01<br>(-0.12) | -0.04<br>(-0.86) |
| $\gamma_9$ | --<br>-- | 0<br>(0.12) | -0.01<br>(-2.77)* | 0<br>(-4.46)* | -0.01<br>(-4.09)* |
| $\gamma_{10}$ | --<br>-- | -0.02<br>(-3.23)* | -0.02<br>(-2.98)* | 0.01<br>(0.94) | 0.02<br>(1.68) |
| $\gamma_{11}$ | 0.01<br>(4.26)* | 0.01<br>(3.36)* | 0<br>(1.37) | 0.01<br>(3.12)* | 0.01<br>(2.97)* |
| $R^2$<br>F | 0.71<br>25.76 | 0.79<br>22.26 | 0.84<br>24.93 | 0.86<br>34.74 | 0.86<br>29.16 |

Notes: 1. The figures in parentheses are t-values.
2. An asterisk (*) indicates significance at 5% level.